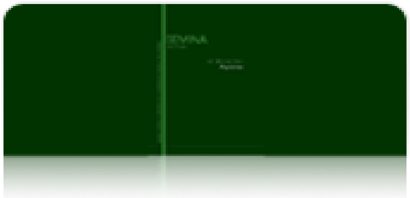

Semina: Ciências Agrárias
ISSN: 1676-546X
semina.agrarias@uel.br
Universidade Estadual de Londrina
Brasil

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Contribution of basal and aerial tillers to forage production dynamics in Tifton-85 bermudagrass irrigated with fishpond wastewater and fertilized with NPK
Semina: Ciências Agrárias, vol. 38, núm. 6, noviembre-diciembre, 2017, pp. 3725-3737
Universidade Estadual de Londrina
Londrina, Brasil

DOI: 10.5433/1679-0359.2017v38n6p3725

Contribution of basal and aerial tillers to forage production dynamics in Tifton-85 bermudagrass irrigated with fishpond wastewater and fertilized with NPK

Contribuição de perfilhos basais e aéreos na dinâmica de produção de forragem do capim-tifton 85 irrigado com efluentes de tanques de piscicultura e recebendo adubação com NPK

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Abstract

This paper aims to assess the contribution of basal and aerial tillers to structural and productive characteristics of Tifton 85 bermudagrass, irrigated with fish tank wastewaters and fertilized with NPK. The experiment was conducted in the city of Petrolina-PE, Northeastern Brazil. The evaluated area had 960 m^2 subdivided into five treatments and ten replicates, in a completely randomized design. Treatments consisted of different fertilization rates of NPK (0, 33, 67, 100, and 150%) as recommended by the Handbook of Fertilization Recommendations for the State of Pernambuco, and based on a prior soil analysis. Irrigation water came from fishponds with Nile Tilapia fingerlings. The experiment was divided into four intervals of 27, 29, 18, and 21 days respective to the first, second, third, and fourth cuts. Both tiller types were analyzed for number of individuals, culm length and diameter, fully- and partially-expanded leaves, leaf length and width (fully or partially expanded), dry mass of leaves (fully and partially expanded and total), culm, dead tissue, and total tiller, and the ratio of leaf and culm. Both structural and productive characteristics showed a linear growth trend for both types, with emphasis on the basal tillers. Thus, a suitable supply of nutrients is crucial for grasses, mainly NPK, as these are macronutrients of vital importance in physiological processes. In addition to the nutrients supplied via fish farming wastewater, fertilization with 150% of the recommended amount of NPK promoted a greater structural development of the tillers, increasing their productivity levels.
Key words: *Cynodon* spp. Fertilization. Tillering. Water reuse.

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Received: Aug. 10, 2016 Approved: Sept. 12, 2017

Resumo

Este trabalho teve como objetivo avaliar a contribuição dos perfilhos basais e aéreos do capim-tifton 85, nas suas características estruturais e produtivas, quando irrigado com efluentes de tanque de piscicultura e recebendo adubação com NPK. O trabalho foi conduzido no município de Petrolina-PE, e a área útil utilizada foi de 960 m^2 dividida em cinco tratamentos e dez repetições, em delineamento experimental inteiramente casualizado. Os tratamentos foram compostos por diferentes níveis de adubação com NPK (0, 33, 67, 100 e 150%) conforme recomendado pelo manual de análise de solo do estado de Pernambuco-PE, sendo que antes das adubações foram realizadas as análises do solo. A água para irrigação foi oriunda de tanques de piscicultura povoados com alevinos de Tilápia do Nilo. O experimento foi dividido em quatro intervalos com 27, 29, 18 e 21 dias para o primeiro, segundo, terceiro e quarto corte, respectivamente. As variáveis analisadas foram: número de perfilhos basais e aéreos, comprimento e diâmetro do colmo, número de lâmina foliar expandida e em expansão, comprimento e largura de lâmina foliar expandida e em expansão das duas categorias de perfilhos, além da massa seca da lâmina foliar expandida, em expansão e total, do colmo, tecido morto e por unidade de perfilho, assim como a relação lâmina foliar/colmo dos dois tipos de perfilhos, basal e aéreo. Verificou-se crescimento linear das características estruturais e produtivas de ambos os perfilhos com destaque para o basal, mostrando assim a necessidade do fornecimento adequado dos nutrientes para as gramíneas, em especial de NPK, macronutrientes de vital importância nos processos fisiológicos e de desenvolvimento. A adubação com 150% do recomendado de NPK, aliada aos nutrientes fornecidos pela água de piscicultura promoveu o maior desenvolvimento estrutural dos perfilhos e a maior produtividade dos mesmos.

Palavras-chave: *Cynodon* spp. Fertilização. Perfilhamento. Reúso de água.

Introduction

Hybridization within and between *Cynodon* sp. species has enabled the development of hybrids with good responses to fertilizations and improved quality compared to common bermudagrass lineages. Tifton 85 (*Cynodon* spp.) is a cultivar that has shown a high potential for forage production and high digestibility in trials conducted in the United States (HILL et al., 1993). Under proper water or irrigation conditions and fertilized with nitrogen (N), phosphorus (P), potassium (K) and other nutrients, this cultivar reaches high rates of forage accumulation (kg dry matter $ha^{-1}.day^{-1}$), achieving yearly yields between 20 and 25 tons DM ha^{-1}, with a high tiller population density.

For forage accumulation, tillers have a fundamental role as a basic unit of production in grasses and are able to generate new tillers from leaf axillary buds. In addition, tillers can originate from basal and axillary buds of a plant; their number and size will depend on factors such as genotype, hormone balance, flowering, light, temperature, photoperiod, water, mineral nutrition, and cut numbers.

Low-order (basal) and axillary (aerial) tillers have particular characteristics able to influence grass growth dynamics. Overall, aerial tillers have higher leaf: culm ratio, are tender and have improved nutritive value when compared to the basal ones. In some cases, tillering from basal nodes tends to be faster than that from top ones (PACIULLO et al., 2003); however, these tillers develop because of pasture management practices.

Although the management techniques to boost the growth of these tillers and improve forage canopy are countless, mineral fertilization and irrigation stand out, mainly for the cultivar Tifton 85 (*Cynodon* spp.), which is quite demanding and responsive to such practices.

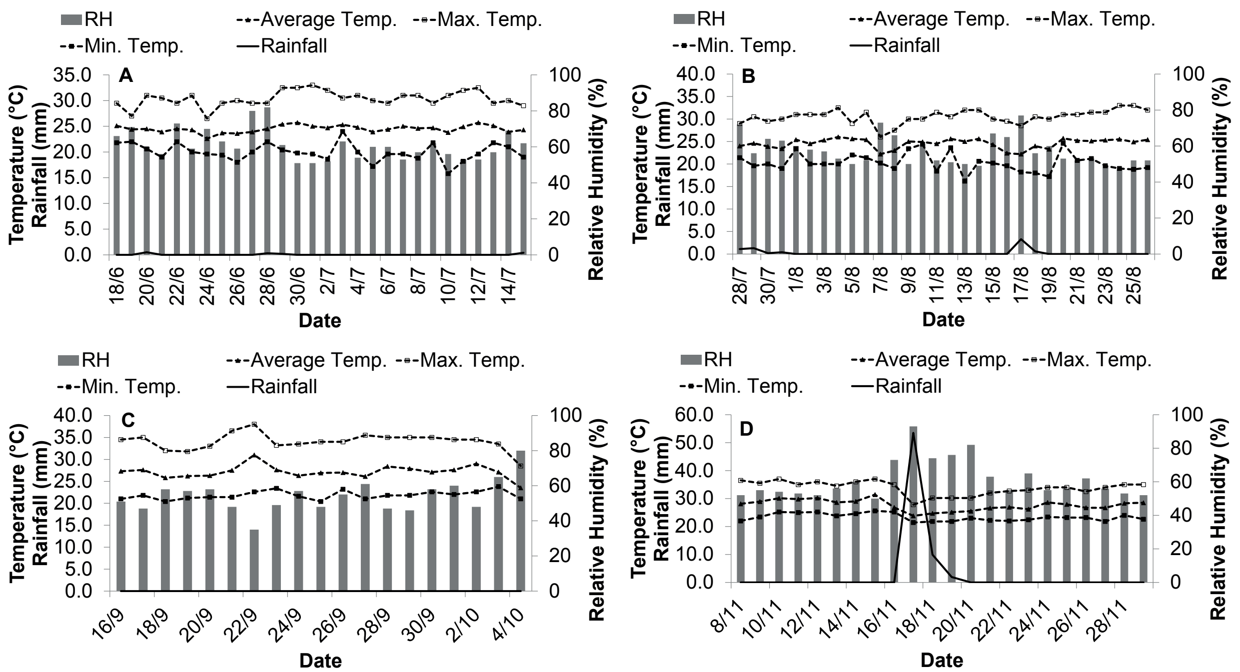
The macronutrients nitrogen, phosphorus, and potassium are of vital importance to forage since these elements are part of proteins, chlorophyll, and enzymes. Combined with fertilization, irrigation with water from fish ponds may be an interesting practice, as this wastewater can provide the soil with organic matter and nutrients, which come from wastes of fish feeding, reducing costs with mineral fertilization. Moreover, this process is eco-friendly since it secures a proper disposal of this wastewater (GENTELINI et al., 2008).

Thus, the goal of this study was to evaluate the contribution of basal and aerial tillers of Tifton 85 bermudagrass to structural and productive characteristics when irrigated with wastewater from fishponds and fertilized with different rates of NPK.

Material and Methods

The experiment was carried out in the irrigated perimeter of Bebedouro, in the city of Petrolina-PE, Brazil. The area is located on a private farm (lot Nº 015A), at the geographical coordinates of 09º09’00”S 40º22’00”W, and altitude of 365.5 m. According to Köeppen’s classification, local climate is a ‘BSwh’ type, with annual mean temperature of 26.3 ºC and relative air humidity of 68 %. Figure 1 shows the meteorological data during the experimental period. The soil is classified as a Yellow Argisol, and a chemical analysis of the 0-20 cm depth showed the following characteristics: pH (H_2O) = 6.30, EC (ds m^{-1}) = 1.93, OM (g kg^{-1}) = 4.58, P (mg dm^3) = 3.19, K ($cmol_c$ dm^3) = 0.22, Ca ($cmol_c$ dm^3) = 2.96, Mg ($cmol_c$ dm^3) = 1.40, and Na ($cmol_c$ dm^3) = 0.05.

Figure 1. Meteorological data (maximum, average, and minimum temperatures in °C, rainfall in mm, and relative humidity in %) gathered from the Bebedouro’s experimental station, Embrapa Semiarido, in Petrolina - PE, Brazil. Data were collected from June 18 to July 15 (A), from July 28 to August 26 (B), from September 16 to October 4 (C), and from November 8 to 29 (D) of 2014.



The experiment lasted six months (from June to November 2014) and was split into four intervals (27, 29, 18, and 21 days), which corresponded to the first, second, third, and fourth cuts, respectively. Each interval comprised from fertilization (treatments) until harvest, characterized by early senescence of the first pair of older emerged-leaves, as a way to avoid forage loss.

As forage, we used Tifton 85 bermudagrass (*Cynodon* spp.), already growing in an area of

5000 m^2, within which a homogeneous area of 960 m^2 made the experimental useful area. This area was divided into five bands with 192 m^2, which stood for the treatments, being subdivided into ten replications (19.2 m^2). The experimental design was completely randomized with five treatments and ten replications. Treatments were five rates of NPK, representing 0, 33, 67, 100, and 150% the values recommended in the Handbook of Soil Fertilization for the State of Pernambuco for grasses (IPA, 2008).

The mineral sources of N, P, and K were urea (45% N), single superphosphate - SS (18% P_2O_5), and potassium chloride - KCl (60% K_2O). Before the first three cut intervals, the soil was analyzed (Table 1), and the fertilizations followed the above-mentioned treatments providing 0, 33, 67, and 100% of the recommendations in the above-mentioned handbook (IPA, 2008). For the fourth cut interval, we used the foregoing soil analysis. Also, treatment five (150%) was not preceded by soil analysis; so the amounts of 60 kg ha^{-1} N and P_2O_5 plus 50 kg ha^{-1} K_2O were applied for the four cut intervals. Micronutrient application was needless. The recommendations of N, P_2O_5, and K_2O and the amounts of urea (N), single superphosphate (SS) and potassium chloride (KCl) applied in each treatment were based on previously determined soil analysis results (Table 2).

Table 1. Soil analysis at a depth range of 0-20 cm, before the first, second, and third cut intervals of Tifton-85 bermudagrass irrigated with fishpond wastewater and fertilized with NPK.

Soil analysis result - Depth 0-20 cm				
Preceding the first cycle				
Treatment	pH (H_2O)	P (mg dm^{-3})	K (Cmolc dm^{-3})	Na (Cmolc.dm^{-3})
0%	6.46	3.12	0.19	0.03
33%	6.56	4.84	0.21	0.03
67%	6.39	9.22	0.20	0.04
100%	6.64	10.13	0.17	0.03
150%	---	---	---	---
Preceding the second cycle				
0%	6.82	5.35	0.21	0.04
33%	6.73	7.64	0.22	0.03
67%	6.53	19.35	0.17	0.02
100%	6.18	24.98	0.15	0.03
150%	---	---	---	---
Preceding the third cycle				
0%	6.96	6.67	0.06	0.03
33%	6.96	17.95	0.06	0.04
67%	6.72	27.27	0.07	0.06
100%	6.55	34.61	0.13	0.03
150%	---	---	---	---

Table 2. Recommendations for nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O) in kg ha^{-1} according to the Handbook of Fertilization Recommendations for the State of Pernambuco (IPA, 2008) for grasses in amounts of urea (N), single superphosphate (SS), and potassium chloride (KCL) in kg ha^{-1}, applied on Tifton-85 bermudagrass pastures prior to the four evaluated cut intervals.

	1º Cut interval						2º Cut interval					
	Recommendation (kg ha^{-1})			Applied (kg ha^{-1})			Recommendation (kg ha^{-1})			Applied (kg ha^{-1})		
	N	P_2O_5	K_2O	N	SS	KCL	N	P_2O_5	K_2O	N	SS	KCL
0%	60	60	50	0	0	0	60	60	50	0	0	0
33%	60	60	50	44	109	28	60	60	50	44	109	28
67%	60	60	50	89	223	57	60	40	50	89	146	57
100%	60	60	50	133	333	86	60	20	50	133	111	86
150%	60	60	50	199	499	129	60	60	50	199	499	129
	3º Cut interval						4º Cut interval					
	N	P_2O_5	K_2O	N	SS	KCL	N	P_2O_5	K_2O	N	SS	KCL
0%	60	60	70	0	0	0	60	60	70	0	0	0
33%	60	40	70	44	73	40	60	40	70	44	73	40
67%	60	20	70	89	74	81	60	20	70	89	74	81
100%	60	20	50	133	111	86	60	20	50	133	111	86
150%	60	60	50	199	499	129	60	60	50	199	499	129

In the first cut interval, the recommendation was similar for all treatments since previous fertilization had not been carried out (Table 1), being of 60 kg ha^{-1} N and P_2O_5, and 50 kg ha^{-1} K_2O. In the second cut interval, P_2O_5 recommendation decreased to 40 kg ha^{-1} for treatment 3 and to 20 kg ha^{-1} for treatment 4, while treatments 1 and 2 remained as in the first. In the third cut interval, treatment 1 recommendations were 60 kg ha^{-1} N and P_2O_5 but 70 kg ha^{-1} K_2O; whereas treatments 2 and 3 recommendations were respectively 40 and 20 kg ha^{-1} P_2O_5 and 70 kg ha^{-1} K_2O for both; in treatment four, it was 20 and 50 kg ha^{-1} P_2O_5 and K_2O, respectively. For the fourth interval, the recommendation was similar to the third one. Treatment 5 (150%) was applied with 60 kg ha^{-1} N and P_2O_5, and 50 kg ha^{-1} K_2O, in all cut intervals. Similarly, treatment 1 (zero %) received no fertilization in the four cutting intervals.

As seen in IPA (2008), nitrogen application in all treatments for maintenance of grasses in irrigated areas was 60 kg ha^{-1} N.

Irrigation was done with water from two fishponds near the experimental area. These tanks sized 30.00 x 70.00 x 1.00 m and were populated with 5000 Nile tilapia (Oreochromis niloticus) fingerlings at a density of 2.4 fish.m-3. These fish received twice-daily feed, at a ratio of 2% adult live weight, which was 0.8 grams. The water supply consisted of a system where the first pond was filled with water from a nearby river and the second tank with the water surplus of the first one. Irrigation water was daily provided from this second tank, being submitted to previous analysis (Table 3). The irrigation was carried out through a conventional sprinkling system, composed of mini sprinklers installed on 1-m long 3/4'' PVC pipes spaced 12.0 m apart. Irrigation was managed based on the evapotranspiration demands of the pasture and climatological data from a weather station in the experimental field of Bebedouro, *Embrapa Semiárido*, in Petrolina-PE.

Table 3. Analysis of wastewater from fishponds used for irrigation during the experimental period.

Analysis of wastewater from fishpond						
N NO_3 mg L^{-1}	P mg L^{-1}	K mg L^{-1}	Mg mg L^{-1}	Ca mg L^{-1}	pH	CE µS cm^{-1}
2.38	0.56	1.15	1.11	4.5	6.7	64.2

The analysis of fishpond wastewater provided data on the contribution of this wastewater to the treatments, in each cut interval. In the first, the analysis revealed a supply of 0.405 kg N, 0.096 kg P, 0.197 kg K, 0.207 kg Mg, and 0.773 kg Ca. In the second, the wastewater contributed with 0.435 kg N, 0.103 kg N, 0.212 kg K, 0.222 kg Mg, and 0.830 kg Ca. In the third, it was 0.270 kg N, 0.064 kg P, 0.131 kg K, 0.138 kg Mg, and 0.515 kg Ca. In the fourth, the contribution was 0.315 kg N, 0.074 kg P, 0.153 kg K, 0.161 kg Mg, and 0.601 kg Ca. It is important to note that these quantities were equally provided to all treatments for all cut intervals.

Evaluations were performed at each grass cut with the aid of a 0.25-m^2 square frame (0.50 x 0.50 m). It was placed on the field surface of each repetition, and all the grass within it cut for sampling. These samples were packed into plastic bags, identified, and then taken to the laboratory. There, the number of basal tillers (NBT/ m^2) was accounted, considering tillers sprouting from nearby basal buds, or at ground level. In addition, we quantified the number of aerial tillers (NAT/ m^2), counting those emerging from lateral buds of the main basal tiller.

After counting, five tillers per category were randomly set aside, totaling 50 tillers per treatment. Then, the following measurements were taken: 1) after removing the younger leaf ligule: base culm length (BCL) and aerial culm length (ACL) using a measuring tape; 2) base and aerial culm diameters (BCD and ACD) using a digital caliper; 3) the numbers of fully-expanded leaves - NFELb and NFELa (with exposed ligule); the numbers of partially-expanded leaves - NPELb and NPELa (with hidden ligule); 4) the lengths of fully-expanded leaves - FELLb and FELLa (from the tip to the ligule) and partially-expanded leaves (from the tip to the ligule of last expanded leaf) - PELLb and PELLa; 5) the widths of fully- and partially-expanded leaves (FELWb and FELWa) with a ruler from one edge to the other in the middle portion of the leaves.

After structural analyses, this material was manually divided into leaf (fully and partially expanded), culm, and dead tissue (above 50% senescent tissue), for both aerial and basal tillers. All morphological components were weighed and packed into labeled paper bags, then taken to a forced-air circulation oven, where were kept at 65 °C for 72 hours. The dried material was weighed for dry matter yields: fully and partially expanded leaves for both basal and aerial tillers (FELDMb, PELDMb, FELDMa, and PELDMa), and total leaf dry matter (TLDMb and TLDMa), in which both fully- and partially-expanded leaves were accounted. In addition, culm dry matter (culm + leaf sheath) for both tillers (CDMb and CDMa) and dead tissue dry matter (DTDMb and DTDMa) were measured. In addition, the dry matter of each tiller unit by summing all the above-mentioned parts (leaf + culm + dead tissue) for both basal (TDMb) and aerial (TDMa) tillers, divided by the number of tillers evaluated per replicate. Finally, the proportion of leaf blade and culm (L: C) was found by dividing these fractions.

As for the structural variables, the dry matter yields were determined by averaging the values of the four cut intervals. The statistical analyses were developed using the software Statistical Analysis System version 9.1 (SAS, 2003), with a previous testing of residual normality by SHAPIRO WILK

(PROC UNIVARIATE function), and means compared by orthogonal contrasts at 5% probability using PROC GLM function. As the fertilization rates were not equidistant, we used the PROC IML function to generate the vectors of each contrast (linear, quadratic, cubic, and cubic deviation). When significant, regression equation parameters were computed by PROC REG.

Results and Discussion

All the fertilization rates had influences on both NAT and NBT per m² ($p<0.05$), and showed an increasing linear equation varying from 267 to 1121 tillers.m-² for rates of zero to 150% NPK, respectively, with regards to recommendations of IPA (2008). Yet for NAT per m², the response was reversed for the fertilizer rates, coming from 6225 to 3261 tillers.m² (Table 4). Our findings are below those reported by Moreira et al. (2015) for NBT per m² (from 2134 to 2440) when assessed the same grass fertilized with N and under continuous stocking. Likewise, Carvalho et al. (2000) found similar results when assessed cultivar Florakirk (Cynodon spp.) under grazing, ranging from 8620 to 13050 tillers.m² but considering all tillers.

Table 4. Averages of structural characteristics of basal and aerial tillers of Tifton-85 bermudagrass irrigated with fishpond wastewater and fertilized with NPK, for the four cut intervals.

Structural variables (Basal and Aerial tillers)	Rates of NPK fertilization (% of recommendation)					SEM
	0%	33%	67%	100%	150%	
NBT (m²)	267	380	569	982	1121	50.20
NAT (m²)	6225	5901	5224	3742	3261	195.22
BCL (cm)	6.00	8.42	12.68	22.80	27.61	1.25
ACL (cm)	2.62	3.42	5.46	13.01	17.59	0.87
BCD (cm)	1.44	1.48	1.62	1.67	1.61	0.02
ACD (cm)	1.02	0.99	1.14	1.25	1.32	0.02
NFELb	5.38	4.98	5.20	6.32	6.60	0.12
NPELb	2.91	3.10	3.34	3.43	2.98	0.05
NFELa	3.90	3.55	3.61	4.56	4.82	0.09
NPELa	2.45	2.54	2.66	2.75	2.63	0.03
FELLb (cm)	4.21	6.37	8.11	12.48	16.59	0.66
PELLb (cm)	4.44	6.67	8.26	13.71	19.24	0.79
FELLa (cm)	2.94	3.98	5.42	10.34	16.65	0.74
PELLa (cm)	3.09	4.27	6.08	11.86	19.23	0.88
FELWb (cm)	0.46	0.50	0.51	0.58	0.63	0.01
PELWb (cm)	0.38	0.45	0.46	0.55	0.62	0.02
FELWa (cm)	0.40	0.42	0.44	0.51	0.61	0.01
PELWa (cm)	0.33	0.37	0.38	0.45	0.52	0.01
Variables	Regression equation (RE)					R²
NBT m²	$\hat{y} = 228.225+6.240x$					0.85
NAT m²	$\hat{y} = 6396.478-21.858x$					0.69

Continue...

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BCL	ŷ = 4.581+0.156x	0.87
ACL	ŷ = 0.848+0.108x	0.86
BCD	ŷ = 1.56	---
ACD	ŷ = 0.984+0.002x	0.57
NFELb	ŷ = 5.201-0.001x+0.00007x^2	0.47
NPELb	ŷ = 3.15	---
NFELa	ŷ = 3.763-0.003x+0.00007x^2	0.47
NPELa	ŷ = 2.61	---
FELLb	ŷ = 3.652+0.084x	0.92
PELLb	ŷ = 3.423+0.100x	0.89
FELLa	ŷ = 1.315+0.093x	0.88
PELLa	ŷ = 1.177+0.110x	0.88
FELWb	ŷ = 0.455+0.001x	0.80
PELWb	ŷ = 0.380+0.001x	0.51
FELWa	ŷ = 0.381+0.001x	0.81
PELWa	ŷ = 0.323+0.001x	0.84

NBT and NAT= Number of basal and aerial tillers; BCL and ACL= Culm length of basal and aerial tillers; BCD and ACD= Culm diameter of basal and aerial tillers; NFELb and NFELa= Number of fully-expanded leaves of basal and aerial tillers; NPELb and NPELa= Number of partially-expanded leaves of basal and aerial tillers; FELLb and FELLa= Lengths of fully-expanded leaves of basal and aerial tillers; PELLb and PELLa= Lengths of partially-expanded leaves of basal and aerial tillers; FELWb and FELWa= Widths of fully-expanded leaves of basal and aerial tillers; PELWb and PELWa= Widths of partially-expanded leaves of basal and aerial tillers; SEM = standard error of the mean; RE = regression equation, R^2 = coefficient of determination.

Despite these slight differences with the literature, in this study, the fertilization rates affected the variables, mainly the basal tillers, which increased significantly when raising NPK doses. As shown by Santos et al. (2009), this is a particular result from nitrogen fertilizations in forage species, which boost population density of tillers. Yet the decrease in NAT can be explained by a compensation mechanism between tiller population size and density found in higher plants, providing a higher population density of lighter tillers (aerial) in low pastures and poorly nourished plants. Such an event can be easily seen at the rate of zero %, in which only the irrigation water served as a source of nutrients, reaching the highest NAT per m². This finding could have occurred because the demanded nutrients lacked added to the mowing to a height of 5 cm, after animal withdrawing from the pasture for standardization. The mowing left the grass low, what hindered recovery if non-fertilized, as in the other treatments; so the grass remain shorter, which stimulates the appearance of numerous small aerial tillers.

From the lowest to the highest fertilizer rate, the culm length of basal tillers ranged from 6.00 to 27.61 cm, and for aerial ones from 2.62 to 17.59 cm, respectively. These findings were adjusted by increasing linear equations, as seen in Table 4. These results corroborate those found by Oliveira et al. (2007) (NK), who combined nitrogen and phosphorus (NP), phosphorus and potassium (PK) and nitrogen, phosphorus plus potassium (NPK) for Tanzania grass, and verified higher values of pseudoculms mainly in combinations containing nitrogen. Longer culms in basal tillers, in addition to nutrition, are derived from a direct relationship with lower population densities of tillers (SANTOS et al., 2010a). In general, aerial tillers are smaller compared to the base ones, so it is natural for the shooting part to be shorter. The mere fact of the aerial tillers originate from lateral buds at nodes in basal tillers is enough to understand their smaller development. In fact, aerial tiller supporting by a main basal tiller is possible due to the robustness of the latter (SANTOS et al., 2010b).

However, when analyzing diameter, we noticed that basal culms had no difference among treatments, with an average of 1.56 cm. By contrast, aerial culms were positively influenced by fertilization rates, with the largest diameter of 1.32 cm at 150% NPK (Table 4). This outcome may be related to the translocation of nutrients from basal to aerial tillers, making them thicker. This effect is common in grasses for the perpetuation of the species, even though it had a significant effect from fertilization, being ACD inferior to BCD.

The number of fully expanded leaves of both tillers exhibited a significant response to fertilization rates, together with nutrients provided by fish farming wastewater. Quadratic equations were adjusted to these results, with the lowest values (4.98 and 3.55 leaves for basal and aerial tillers) at the rate of 33%, while the highest numbers were found at 150% (6.60 and 4.82 leaves for basal and aerial tillers). This response is due to fact that potassium works in the activation of several enzymatic systems, some of them involved in photosynthesis and respiration processes. In addition, nitrogen promotes physiological changes, mainly in the number of leaves, and phosphorus acts on transport and energy use in photosynthesis, which are factors with direct relation to leaf blade growth.

Interestingly, the largest number of fully expanded leaves in basal tillers also comes from their greater development if compared to the aerial ones. Thus, basal tillers generate more phytomers and, hence, a higher number of fully expanded leaves. Yet the number of partially expanded leaves was not influenced by fertilization rates, in any of the tillers (NPELb and NPELa), with averages of 3.15 and 2.61 leaves, respectively (Table 4). Perhaps this non-significance may be tied to specific features of these plants. Our findings corroborate Santos et al. (2010b), who evaluated *Brachiaria decumbens* under continuous stocking and found significant responses and more fully expanded leaves in basal tillers than in aerial ones, besides falling short of the numbers found for *Cynodon* spp. cv. Tifton-85 (5.4 live leaves per tiller) as described by Pinto (2000).

A study conducted by Pereira et al. (2011) on morphogenic and structural characteristics of Tifton-85 grass, under nitrogen rates and cut heights, showed no effect of cutting height and nitrogen doses on the number of live leaves per tiller ($p > 0.10$). The same authors found averages of 9.10 and 10.06 live leaves in the first and second growing years, respectively. However, these values are lower than those found here if we consider fully- and partially-expanded leaves for both aerial and basal tillers all together, especially in treatments with higher fertilization rates. According to the aforementioned authors, even with a stable number of live leaves per tiller, the time required by Tifton 85 tillers to reach their maximum number of leaves is short when higher doses of nitrogen are applied, showing this mineral may speed up cell divisions.

Through Table 4, we may note that fully- and partially-expanded leaf length and width for both tillers (basal and aerial) were influenced by NPK fertilizations, showing an increasing linear effect. Non-fertilized plants (zero%) and those receiving the highest fertilization rate (150%) reached lengths of 16.59, 19.24 and widths of 0.63, 0.62, respectively, as well as the following values of 16.65, 19.23 and 0.61, 0.52 for FELLa, FELWa and PELLa, PELWa.

In studies with brachiaria grass under continuous stocking and after deferred grazing, respectively, Santos et al. (2010b, 2014) noticed that the leaf blade of basal tillers was longer than that of aerial tillers, being different from what we found here, wherein these lengths were similar. Comparing both partially- and fully-expanded leaves, the first ones were longer than the latter for both tillers. Premazzi et al. (2011) fertilized Tifton 85 grass with nitrogen after cuts and found positive responses to leaf blade length, with mean values of 19.3 and 15.8 cm after the first and second cuts, applying doses of 162 and 187 mg kg^{-1} nitrogen to the soil. Gomide et al. (2003) emphasized the importance of environmental factors, mainly temperature, photoperiod, and lightness, on leaf appearance and elongation rates, favoring LAI index and, hence, forage accumulation. In fact, it would be appropriated to reiterate that grass morphophysiological processes are sensitive to unfavorable climatic conditions related to suitable water availability and temperature, as well as nutrient supply. In this context, favorable conditions for Tifton-85 grass growth were provided in our study, given the photoperiod of the studied region, the irrigation provided, and the nutrients incorporated into the soil. Nutrients that are provided both in chemical form by the applied treatments, and in organic form by the fish farming wastewater, providing essential macronutrients such as nitrogen, phosphorus, and potassium (Table 3), which are crucial for the growth of forage grasses.

All the productive variables related to dry matter were influenced by fertilization rates and adjusted to linear equations. The results showed that as fertilization rates were raised, the dry matter yields were elevated as well (Table 5). The highest yields were found when applying 150% of the recommended NPK dose, as proposed by IPA (2008). These values for basal tillers were of 0.73, 0.40, 1.13, and 1.34 g for FELDMb, PELDMb, TLDMb, and CDMb, respectively. Yet for the aerial tillers, they were of 0.44, 0.29, 0.73, and 0.61 g for FELDMa, PELDMa, TLDMa, and CDMa, respectively.

Table 5. Averages of productive variables (in dry matter) of basal and aerial tillers of Tifton-85 bermudagrass irrigated with fishpond wastewater and fertilized with NPK, for the four cut intervals.

Productive variables (Basal and Aerial tillers)	Rates of NPK fertilization (% of recommendation)					SEM
	0%	33%	67%	100%	150%	
FELDMb (g)	0.16	0.22	0.28	0.55	0.73	0.03
PELDMb (g)	0.09	0.13	0.19	0.35	0.40	0.02
TLDMb (g)	0.25	0.35	0.47	0.90	1.13	0.05
FELDMa (g)	0.06	0.07	0.11	0.28	0.44	0.02
PELDMa (g)	0.04	0.05	0.08	0.19	0.29	0.01
TLDMa (g)	0.10	0.12	0.19	0.47	0.73	0.03
CDMb (g)	0.30	0.43	0.69	1.29	1.34	0.07
CDMa (g)	0.10	0.09	0.17	0.44	0.61	0.03
TDMb (g)	0.12	0.17	0.26	0.46	0.51	0.02
TDMa (g)	0.04	0.05	0.08	0.19	0.28	0.01
DTDMb (g)	0.06	0.07	0.13	0.13	0.09	0.01
DTDMa (g)	0.02	0.03	0.04	0.06	0.03	0.01
L: C/B	0.91	0.87	0.76	0.75	0.90	0.02
L: C/A	1.26	1.35	1.17	1.16	1.22	0.03

Variables	Regression equation (RE)	R^2
FELDMb	$\hat{y} = 0.103+0.004x$	0.88
PELDMb	$\hat{y} = 0.074+0.002x$	0.85
TLDMb	$\hat{y} = 0.180+0.006x$	0.90

Continue...

Continuation...

FELDMa	ŷ = 0.004+0.0026x	0.80
PELDMa	ŷ = 0.008+0.0017x	0.84
TLDMa	ŷ = 0.012+0.0044x	0.83
CDMb	ŷ = 0.256+0.008x	0.78
CDMa	ŷ = 0.016+0.0038x	0.81
TDMb	ŷ = 0.102+0.003x	0.85
TDMa	ŷ = 0.009+0.0016x	0.84
DTDMb	ŷ = 0.09	---
DTDMa	ŷ = 0.03	---
L: C/B	ŷ = 0.84	---
L: C/A	ŷ = 1.23	---

FELDMb, PELDMb, and TLDMb= Leaf blade dry matter, fully- and partially expanded and total of basal tiller; FELDMa, PELDMa and TLDMa= Leaf blade dry matter, fully- and partially expanded and total of aerial tiller; CDMb and CDMa= Culm dry matter of basal and aerial tillers; TDMb and TDMa= Total dry matter of basal and aerial tillers; DTDMb and DTDMa= Dead tissue dry matter of basal and aerial tillers; L: C/b and L: C/a= Ratio between leaf blade and culm of basal and aerial tillers; SEM = standard error of the mean; RE = regression equation, R² = coefficient of determination.

Although both tiller types had similar responses regarding the growth of the aforementioned variables, the aerial ones showed inferior weight due to its structure. These results corroborate Santos et al. (2014), who reported lower rates of leaf and pseudoculm elongations in aerial tillering, also justifying thus their lower weights if compared to the basal structures.

Given their direct correlation with the other organs, the dry matter contents by unit of basal and aerial tiller followed the same trend of linear growth, with averages of 0.51 and 0.28 g per unit at the highest fertilization rate (Table 5). Santos et al. (2010a) found a positive association of culm length and number of leaves with the tiller weight.

Similarly, Martuscello et al. (2006), when evaluating massai grass fertilized with nitrogen and submitted to defoliation, recorded increases in dry mass production for leaf and culm as nitrogen doses were raised. Evaluating the cultivars Tifton-85 and Jiggs fertilized with macronutrients, Rezende et al. (2015) observed the highest yields of leaves, stems, tillers, and dry weights when using the fertilizers 20-10-10 and 08-28-16. According to these authors, this fact occurred for the presence of phosphorus in these formulas, once they used the fertilizer 30-00-20, and it limited the yields of leaves, culms, tillers, and dry mass. As for Coutinho et al. (2014), when studying liming and potassic fertilizations for Tifton-85, they verified that growing doses of K promoted significant increases in forage dry mass, reporting rises of about 86% in the first cut comparing plants without K supply and those receiving the highest dose of this nutrient.

Nutrients are limiting factors for grass development. Nitrogen, phosphorus, and potassium, known as macronutrients, are essential to these plants, and they can be provided organically or minerally. As such, we may state that the positive responses of Tifton-85 obtained here are associated with the supply of these macronutrients to the grass both way. Nitrogen, phosphorus, and organic matter are the main elements found in fish farming wastewater and their contents may vary widely with the way fish are reared (intensive or semi-intensive), besides the type of feed provided.

Accordingly, several researchers have reported the importance of macronutrients (nitrogen, phosphorus, and potassium) for grasses. Horchani et al. (2011) cited nitrogen as the most important nutrient for tiller development and culm size. Yet Malta (2009) reported about the role played by phosphorus in the early establishment of grasses acting in plant respiration and influencing energy storage, transportation, and use in photosynthesis, as well as on root growth. As for K, nutritional requirements are related to four biochemical and physiological roles: enzymatic activation, membrane transport processes, anionic neutralization, and osmotic potential (DECHEN; NACHTIGALL, 2007).

Regarding DTDM and the ratio L: C, neither tiller types had significant results, showing averages of 0.09 and 0.84 (DTDMb and L: Cb) and of 0.03 and 1.23 (DTDMa and L: Ca), respectively (Table 5). The relationship leaf blade and culm is commonly used as a parameter of nutritional quality but it varies a lot with the forage species, being smaller in species with tender culms and less lignification (SBRISSIA; SILVA, 2001). With respect to DTDM, such non-significant response ($p > 0.05$) is interesting since plenty of studies reported in the literature have shown a rise in the senesced material as fertilization is enhanced, particularly with nitrogen. We may infer that the amounts of nutrients applied in our research are within the crop needs. Therefore, the smaller content of dead tissue in the aerial tillers compared to the basal ones might have been a compensation in tissue flow, wherein the lower growth rate of the organs (leaves and culms) was counterbalanced by a slight senescence.

Conclusion

Application of 150% recommended dose, as proposed in the Handbook of Fertilization Recommendations for the State of Pernambuco by IPA (2008), combined with irrigation using fishpond wastewater can linearly increase structural and productive characteristics in both basal and aerial tillers of Tifton-85 bermudagrasses, with emphasis on the basal tillers.

Acknowledgements

The authors want to thank the Coordination for Improvement of Higher Education Personnel (CAPES) for the financial support for the research development.

We also thank the owners of lot No. 015A, located in the irrigation project of Bebedouro, in Petrolina-PE (Brazil), for providing the experimental area.

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